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Abstract

DEVELOPMENTS IN SPECTRAL-SHIFT REACTORS

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The spectral shift control reactor is a variation of the pressurized water reactor which shows promise of reducing both fuel and capital costs significantly. In this reactor a large portion of the excess reactivity which must be built into a PWR core to achieve long core life is balanced out by modifying the neutron spectrum so that resonance absorption in fertile material is markedly increased. This "shift" of the neutron spectrum is produced by mixing a certain amount of heavy water with the ordinary water in the primary system. As the core is operated the concentration of heavy water is decreased to reduce resonance absorption and thus make more neutrons available to continue the chain reaction.

By shifting the neutron spectrum towards the resonance region at the beginning of operation with a new core, the fertile material acts as a control rod except that the neutrons which would normally be lost to the fuel cycle produce new fuel. This results in a significant improvement of the conversion ratio - in particular when operated with the Uranium 2-33/Thorium fuel cycle near breeding.

The use of a uniform method of shim control eliminates the distortions of the power distribution caused by control rods, making it possible to obtain a high degree of power flattening over the entire core life by proper distribution of fuel in the reactor core. The resulting improvement in power density results in significant savings in plant capital costs.

The principle of spectral-shift control has been confirmed by an extensive series of critical and exponential experiments. Data from these experiments, which have been in progress since July 1960, are presented and include measurements of buckling, cadmium ratios for fission and capture in fertile material, thermal-disadvantage factors, reflector savings, neutron age, change of buckling with temperature and neutron spectra. These

measurements have been made in several lattices at several concentrations of heavy water for 2½%-and 4%-enriched UO_2 and 93%-enriched UO_2/ThO_2 fuels.

The experimental data are correlated by a multigroup diffusion model which uses a Greuling-Geortzel slowing-down kernel. Resonance absorption is calculated by methods similar to those developed by Chernick and Nordheim and is normalized to agree with measured resonance integrals.

Design optimization studies are presented, with particular emphasis on minimizing generating cost. Various fuel-management schemes are considered. The effect of spectral-shift control on the conversion ratio and on uranium utilization is presented.

The economic potential for spectral-shift reactors operating on the uranium-233/thorium fuel cycle is compared with ordinary water reactors. The main features of a prototype plant, the construction of which is expected to begin in 1964, and plans for demonstrating the uranium-233/thorium fuel cycle in the prototype plant are presented.